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54 Process for removal of sulfur from moisture-bearing, sulfur-containing hydrocarbon process streams.

57 A process wherein a particulate sorbent mass of zelite which has been ion-exchanged with zinc or cadmium to provide pore size openings of about 5A (5×10^{-10} m), and greater, particularly zinc, is contacted with a moist hydrocarbon process stream which contains sulfur, sulfur compounds, and other contaminants, these being adsorbed onto said particulate sorbent mass, and the process stream thereby denuded of said sulfur, sulfur compounds, and other contaminants. Thereafter, the sulfur, sulfur compounds, and other contaminants, are readily desorbed, or removed from said particulate sorbent mass by contacting, and purging same with a gas stream, suitably hydrogen, or a hydrogen-containing gas, at elevated temperature.

EP 0 056 197 A1

PROCESS FOR REMOVAL OF SULFUR FROM MOISTURE-BEARING SULFUR-CONTAINING
HYDROCARBON STREAMS

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The present invention relates to a process for the removal of sulfur from moisture-bearing, sulfur-containing hydrocarbon process streams.

Sulfur occurs in many industrial processes, and sulfur, or sulfur containing compounds, for varying reasons must often be removed from process streams, e.g., flue gas, waste gas or recycle gas streams. This has been accomplished, e.g., by contacting the sulfur-containing process stream with a sorbent comprising a particulate oxide, hydrated oxide, or hydroxide of alumina, zinc, or iron; nickel, cobalt or the like, alone or in admixture, with each other or with additional materials, e.g., alkali or alkaline earth metal oxides or the like. Reference is made, e.g., to U.S. 3,492,083 and British Patent 871,076 (1957) which describes processes of this type. Hot spherical pebbles have also been used to remove sulfur from process streams, as described, e.g., in U.S. 2,551,905.

The quality of these sorbents for the removal of sulfur varies considerably, and in many applications it is necessary to scrub essentially all of the sulfur from the process streams. This is done for process reasons, as well as environmental reasons. Sulfur, for example, is a well known catalyst poison which finds its way into a process principally via the feed, and it can gradually accumulate upon and poison a catalyst. Essentially all petroleum feeds contain sulfur. Most of the sulfur, because of this adverse effect, is generally removed from the feed, e.g., by contact with nickel or cobalt oxide guard chambers.

Catalytic reforming, or hydroforming, a well known and important process employed in the petroleum refining industry for improving the octane quality of naphthas and straight run gasolines, is illustrative of a process where the presence of sulfur can have a detrimental effect. Sulfur unavoidably enters the process, principally as a part of the feed. In a typical reforming process, a series of reactors are provided with fixed beds of sulfided platinum-containing catalysts which are sequentially contacted with a naphtha feed, and hydrogen, and each reactor is provided with a preheater, or interstage heater, because the reactions which take place are endothermic. C₅+

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1 hydrocarbons as a product is taken from the last reactor
2 of the series, and a hydrogen-sulfide contaminated hydrogen
3 gas stream is separated therefrom and recycled to the
4 several reactors of the series.

5 In use of the more recently developed multi-
6 metallic platinum catalysts wherein an additional metal, or
7 metals, hydrogenation-dehydrogenation component, is added as
8 a promoter to the platinum, it has become essential to
9 reduce the feed sulfur to only a few parts, per million
10 parts by weight of feed (ppm), because of the sulfur sen-
11 sitiveness of these catalysts. For example, in the use
12 of platinum-rhenium catalysts it is generally necessary to
13 reduce the sulfur concentration of the feed well below
14 about 10 ppm, and preferably well below about 2 ppm, to
15 avoid excessive loss of catalyst activity and C+ liquid
16 yield.

17 The sulfur must also be scrubbed from the
18 hydrogen recycle gas stream because this too is a source
19 of catalyst sulfur contamination. The vapor effluent from
20 the last reactor of the series is thus a gas rich in
21 hydrogen, which generally contain hydrogen chloride and
22 chlorine, as well as hydrogen sulfide, moisture and small
23 amounts of normally gaseous and C₅-C₉ hydrocarbons. It is
24 essential to separate hydrogen from the C+ liquid product
25 and recycle it to the process; and it is essential to re-
26 move the sulfur from the moist recycle hydrogen gas stream.
27 This, as suggested, has been accomplished by the use of
28 guard chambers filled with metal oxides, e.g., zinc oxide,
29 supra. Zinc oxide thus has been used as a sorbent
30 for selectively removing hydrogen sulfide from process
31 streams. Usually, the zinc oxide is contacted with the gas
32 at elevated temperatures to scrub out the sulfur. Such
33 sorbent, however, has not proven successful because the
34 adsorption rate is too low, and it has not been possible
35 to regenerate such sorbent in a reducing atmosphere such
36 as hydrogen due to the high thermodynamic stability of zinc
37 oxide. Zinc oxide, however, is less volatile than most
38 metals, and its volatility is reduced at high temperature.

sulfide. Regeneration of this material requires oxidation of the sulfur, or sulfur-containing compounds, so that the sulfur is evolved as sulfur oxides, an environmentally unacceptable product. Such regeneration impairs the mechanical strength of the material. Moreover, sulfur oxides are difficult to remove from flue gas effluents, e.g., as contrasted with hydrogen sulfide which is easily scrubbed from the stream with a caustic or amine solution.

Wolf and co-workers studied the adsorption of hydrogen sulfide and methyl mercaptan on exchanged syn-Na₂SiO₃ sodium -- A zeolites as a function of the degree of cation exchange. F. Wolf, W. Hoesse & H. Fuertig (Martin-Luther Univ. Halle-Wittenberg; Chemiekombinat Bitterfeld VEB) Chem. Tech. (Leipzig) 27 #5:362-64 (June 1975). For hydrogen sulfide, the capacities were found to decrease in the order barium < potassium < strontium < cobalt < nickel < zinc < manganese < sodium < magnesium < calcium. For methyl mercaptan the capacities were found comparable. The capacities of sodium X and sodium-potassium A sieves for both sulfur compounds were slightly higher than those of the corresponding A sieves. In earlier work some members of the same group has found that zinc-A was relatively poor in adsorbing mercaptans. F. Wolf & K. H. Bergk (Univ. Hauc) Erdoel Kohle, Erdgas, Petrochem Brennst.-Chem. 27 #10:629 (Oct. 1974); and this work was later confirmed by Soviet researchers E. I. Shcherbina, V. A. Yakubovich & L. I. Mikhalkayá (Beloruss. Technol. Inst., Minsk) Neftekhimya 17 #1:151-55 (Jan. - Feb. 1977). German Patent 2,226,531 which issued June 1973 to Gebr Herrmann discloses that Pb zeolites can be used for hydrogen sulfide sorption, and that the lead can be exchanged by other metals, inclusive of zinc. The Patentee, however, states that such exchanged zeolites have not been found of practical use.

Robert M. Milton's U.S. Patents 3,078,640 and 3,024,868, which issued on applications filed in the last weeks of the year 1959, are believed to exemplify the

1 state-of-the-art as relates to the separation of sulfur-
2 containing compounds from gaseous mixtures by the use of
3 molecular sieve adsorbents. In U.S. 3,078,640, which
4 issued February 26, 1963, certain forms of zeolite A are
5 suggested for use in the selective adsorption of hydrogen
6 sulfide from a vapor mixture containing at least one mem-
7 ber of the group consisting of hydrogen, carbon dioxide,
8 and normal saturated aliphatic hydrocarbons containing
9 less than nine carbon atoms per molecule. The reference
10 suggests that zeolite A can be used in its sodium form,
11 or the sodium ions of the zeolite can be substituted at
12 least in part by other metal ions from Group I and Group II
13 of the Periodic Table. The reference states that the various
14 ion exchanged forms of zeolite A includes the lithium,
15 ammonium, silver, zinc, nickel, hydrogen and strontium
16 forms. It is stressed that the divalent metal substituted
17 forms of zeolite A, e.g., zinc, nickel and strontium zeo-
18 lite A, behave quite differently from the monovalent metal
19 substituted forms of zeolite A, e.g., lithium, and hydro-
20 gen zeolite A. It suggests that any cationic form of
21 zeolite A having a pore size of at least 4 Angstroms is
22 suitable for practicing the invention; and conversely that
23 smaller pore size forms are unsatisfactory because they do
24 not admit hydrogen sulfide and mercaptans. Albeit, how-
25 ever, this reference describes the use of molecular sieves
26 having pore sizes greater than 4A as a selective adsorbent
27 for the separation of sulfur-containing compounds from hydro-
28 carbons, there is no suggestion of the separation, or ad-
29 sorption, of sulfur containing compounds from moisture
30 bearing, or water containing streams. The separation of
31 sulfur compounds from moist, or wet streams presents a far
32 more difficult problem inasmuch as water is preferentially
33 adsorbed to the exclusion of sulfur containing compounds,
34 and e.g., water generally replaces essentially all of the
35 hydrogen sulfide from an adsorbent contacted with a stream
36 containing both water and hydrogen sulfide.

37 On the other hand, in U.S. 3,024,868, which

* 1 Angstrom (A) = 1×10^{-10} m

0056197

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1 issued March 13, 1962, there is specifically described a
2 process, useful for the separation of sulfur containing
3 compounds from moist vaporous streams. In particular, the
4 process described is one useful for removing moisture
5 sulfur containing compounds, notably hydrogen sulfide, from
6 the recycle hydrogen gas stream of a reformer by contact
7 of the stream with crystalline zeolitic molecular sieves
8 having pore sizes ranging from about 3.6 to 4 Å. Both the
9 water and sulfur containing compounds are sorbed preferen-
10 tially, to the exclusion of the saturated paraffinic
11 hydrocarbons. It is expressly stated that molecular sieves
12 having larger pore sizes, viz. >4 Å, strongly preferentially
13 adsorb and concentrate the C₄ and higher paraffins. Any
14 substitution of the sodium zeolite A with monovalent or
15 divalent metal ions which enlarges the pore size beyond
16 this limit is thus, according to Milton, to be avoided.
17 This adverse effect, according to Milton, is particularly
18 apparent with divalent cation forms of zeolite, the en-
19 largement being manifested above about 25 percent substi-
20 tution of divalent ions in the molecular sieve structure.
21 Data presented in the patent shows that zeolite 4A has
22 eight to ten times the adsorptive capacity for water and
23 hydrogen sulfide as zeolite 5A and zeolite 13X, with con-
24 current high exclusion or rejection of the hydrocarbons.
25 In Milton's process a reformer recycle hydrogen
26 gas stream is desulfidized by contact with at least two
27 separate beds of the zeolite 4A, the wet reformer hydrogen
28 gas stream being contacted with a first bed in an adsorp-
29 tion stroke at relatively low temperature and pressure,
30 while water and sulfur containing compounds are desorbed
31 from a second bed in a desorption stroke at relatively
32 high temperature and pressure. The flows between the beds
33 are periodically reversed such that the first bed is on an
34 adsorption stroke while the second bed is on a desorption
35 stroke, and vice-versa. Subsequent claims to the use of
36 Whereas commercial processes based on the use of
37 metal oxides for adsorption of sulfur from process streams

1 have provided varying degrees of success, there is
2 little evidence that the zeolites have attracted any
3 significant commercial interest, if any, for this use.
4 A considerable need therefore exists for the development
5 of new and improved processes of this type, especially
6 those which are capable of adsorbing, and separating
7 sulfur-containing compounds from moist hydrocarbon streams;
8 notably hydrogen sulfide-containing reforming hydrogen
9 recycle gas, or similar sulfur-containing gases.
10 It is an object of this present invention to
11 provide a new and improved process, particularly one titi-
12 lizing a sorbent which is capable of high rates of sulfur
13 adsorption from process streams, and more particularly one
14 which can be regenerated without significant loss of
15 mechanical strength, if any such loss is unavoidable. (Group 10)
16 This object is achieved in accordance with the
17 present invention, embodying a process wherein a particulate
18 sorbent mass of zeolite which has been ion-exchanged with
19 zinc or cadmium, particularly zinc, sufficient to provide
20 pore size openings greater than 4 Å, preferably 5 Å and
21 greater, most preferably from about 5 Å to about 13 Å, is
22 contacted with a moisture bearing hydrocarbon process
23 stream which contains sulfur, sulfur compounds, and other
24 contaminants, these are adsorbed onto said particulate
25 mass of ion-exchanged zeolite; and the process stream
26 thereby denuded of said sulfur, sulfur compounds, and other
27 contaminants. Thereafter, the sulfur, sulfur compounds,
28 and other contaminants, are readily desorbed, or removed
29 from said particulate mass of ion-exchanged zeolite by
30 contacting, and purging same with a gas stream, suitably
31 hydrogen, hydrogen-containing gas, or inert gas such as
32 nitrogen or methane at elevated temperature.

33 Various zeolites ion-exchanged with zinc or
34 cadmium metals are useful in accordance with this inven-
35 tion inclusive of intermediate and large pore zeolites.
36 Preferred ion-exchanged zeolites include mordenite,
37 faujasite, erionite, ferrierite, zeolite A, ZSM-5, zeolite X

1 and Y, chabazite, both natural, and synthetic, having
2 pore size openings greater than 4A, preferably 5A and
3 greater; especially those having pore size openings
4 ranging from about 5A to about 13A. The A type zeolite
5 is preferred, especially one which is ion-exchanged with
6 a zinc salt, sufficient to provide pore size openings of
7 about 5A, and greater. Exchange of at least about 25 per-
8 cent, and certainly 65 percent of the sodium ions of an
9 A type zeolite with zinc, or cadmium, is found to produce
10 zeolite 5A. In fact, it is found that the adsorption
11 behavior of most of the zeolites, especially zeolite A,
12 begins to change when greater than about 25 percent of
13 the sodium ions are exchanged with the multivalent cation,
14 zinc or cadmium, the pore size openings increasing their
15 normal sizes, especially zeolite A which increases beyond
16 4A. Such divalent forms of zeolite A are found far more
17 effective for the selective adsorption of sulfur containin-
18 compounds than the small pore species of zeolite A pre-
19 viously known for such use, supra. In a preferred operation, a particulate mass of
20 ion-exchanged zeolite, notably zinc exchanged zeolite, is
21 charged, or packed into a guard chamber, or series of guard
22 chambers. Most preferably, the series of zinc exchanged
23 zeolite guard chambers are employed in parallel, this per-
24 mitting active use of one guard chamber, or set of serially
25 aligned guard chambers for contact, and purification of a
26 process stream while the other guard chamber, or set of
27 serially aligned guard chambers, is cut out of series for
28 regeneration. In the treatment of a hydrogen recycle gas
29 stream, as employed in reforming, it is found that the
30 hydrogen sulfide can be readily adsorbed from the stream
31 despite the high moisture content of the gas. This is
32 mildly surprising because it is well known that the selec-
33 tivity of many sorbents for hydrogen sulfide is adversely
34 affected in the presence of water. As a class, the zeolites,
35 in particular, show a preferential adsorption of water, this
36 resulting in a low capacity of the zeolites for the selective

1 removal of hydrogen sulfide. The zinc, and cadmium-
2 exchange zeolite, notably the zinc exchanged zeolite,
3 shows a high capacity for adsorption of the hydrogen
4 sulfide, several times that of many sulfur sorbent materials.
5 No special preparation of the particulate ion-exchanged zeo-
6 lite of this invention is required, and it can be employed
7 in a guard chamber as powder, spheres, tablets, pellets,
8 extrudates, irregular shaped particles, or the like in
9 virtually any size. It is noted that yielded results, the
10 temperature of contact is not critical,
11 and there is no necessity to heat or cool the process.
12 stream, notably the recycle gas stream. Suitably, the
13 recycle hydrogen stream is contacted with the particulate
14 zinc exchanged zeolite sorbent at normal gas stream tempera-
15 tures, i.e., at temperatures ranging from about ambient to
16 about (500°F), or more generally at temperatures ranging
17 from about (100°F) to about (300°F). In preferred practice,
18 it would appear, surprisingly, that the metal
19 atoms of the zeolite structure, notably the zinc atoms of
20 the zinc exchanged zeolite, forms simple adsorption bonds
21 with the sulfur compound, this being sufficient to remove,
22 e.g., hydrogen sulfide from a recycle hydrogen gas stream.
23 Unlike the mechanism involved in the removal of a sulfur
24 compound, e.g., hydrogen sulfide, from a recycle hydrogen
25 gas stream by the use of zinc oxide, there is no chemical
26 reaction wherein zinc sulfide is formed. Apparently, as
27 a consequence thereof the zinc exchanged zeolite is readily
28 regenerated by simply purging, or sweeping the sulfur com-
29 pound therefrom with a hot, non-reactive, or inert gas
30 after it has become sufficiently saturated with the sulfur
31 compound. In the preferred practice of this invention, the
32 zinc exchanged zeolite is simply contacted, purged, or
33 swept with a hydrogen gas stream at elevated temperature to
34 remove the hydrogen sulfide, and other sulfur compounds, and
35 thereby regenerate the zinc exchanged zeolite. Suitably,
36 the purge is conducted by maintaining the hydrogen gas at
37 temperatures ranging from about (300°F) to about (1200°F),
and to purge said zeolite until saturated.

0056197

- 9 -

260°C 537.8°C

1 preferably from about (500°F) to about (1000°F). Since
2 burning in the presence of oxygen as practiced in the
3 regeneration of many sorbents is unnecessary, the
4 hydrogen sulfide is recovered as hydrogen sulfide rather
5 than as sulfur oxides. Consequently, the hydrogen gas
6 stream itself is readily cleansed of the hydrogen sulfide
7 by washing the gas with a caustic or amine solution.

8 The invention will be more fully understood
9 by reference to the following examples, and comparative
10 data which demonstrate the high selectivities for hydrogen
11 sulfide of the zeolites of this invention in the presence
12 of water. All terms are given in weight units except as
13 otherwise specified.

§ 14. EXAMPLES

15 A series of different commercially known zeolites,
16 as identified hereafter, were exchanged with an aqueous
17 solution of zinc chloride, $ZnCl_2$. This was followed by
18 filtration and washing until the filtrate was free of
19 chloride as determined by testing with an $AgNO_3$ solution.
20 The zeolites were then vacuum dried, and calcined in air
21 for three hours at $426.7^\circ C$. To measure H_2S adsorption, the
22 zeolite was packed into a quartz reactor maintained at $93.3^\circ C$
23 ($200^\circ F$) and a stream of 2000 ppm. H_2S in H_2 at atmospheric
24 pressure passed through until breakthrough occurred. This
25 was observed by the discoloration of lead acetate paper.
26 For regeneration, the adsorbents were heated either to $260^\circ C$
27 ($500^\circ F$) or to $(932^\circ F)$ while stripping with H_2 gas. The adsorp-
28 tion of H_2S was then redetermined at a standardized temperature
29 of $(200^\circ F)$. Data on several Zn exchanged zeolites are shown
30 in the Table and/or compared with the unexchanged or
31 corresponding natural zeolite.

Table 1

Exchanged Zeolites

Adsorbent	Zn Exchanged	Wt. % S Adsorbed @ (200°F), 1 Atm.		After 500°C H ₂	After 260°C H ₂
		Original	Cycle 1 Strip		
Na Zeolite A (4A Sieve)	0	0.22	-	-	-
Zn Zeolite A (Zn 5A)	14.5	65	2.37	3.02	2.0
Cd Zeolite A	50	-	2.38	1.27	-
Ni Zeolite Aa	16	-	0.76	0.58	-
Co Zeolite Aa	42	-	0.85	1.40	-
Cu Zeolite Aa,b	772	-	0.47	0.04	-
Hg Zeolite Aa,b	100	-	0.40	-	-
Zn Exchanged	-	-	-	-	-
Erionite	5.79	-	1.12	-	-
Natural Chabazite	0	0	0.96	-	-
Zn Chabazite	6.33	-	1.51	1.87	-
Na Mordenite	0	0	1.08	-	-
Zn Mordenite	3.67	-	1.25	-	-
26. a partial destruction of the zeolite A crystal structure					
27. occurred during the ion-exchange.					
28. bAssuming +2 valence state for Cu and Hg.					
29. From these data, it will be initially observed					
30. that the original sodium zeolite A (4A sieve) had very					
31. limited capacity for H ₂ S under these conditions. The Zn					
32. 5A form, however, had a capacity nearly ten times as great.					
33. Furthermore, a simple hydrogen strip was effective for					
34. regeneration of the sorbent. The increase in capacity in					
35. going from 2.37 wt. % in Cycle 1 to 3.02 wt. % in Cycle 2					
36. is attributable to the higher (932°F) regeneration tempera-					
37. ture compared to the (800°F) original air calcination. The					
38. regeneration at (500°F) is effective in restoring capacity					
39. in Cycle 3 to nearly that observed in Cycle 1.					
40. The sodium form of zeolite A has the formula					
41. Na ₁₂ [(AlO ₂) ₁₂ (SiO ₂) ₁₂]·XH ₂ O, this material being designed					

1 4A because 4A approximates the effective pore size
2 openings of this material in Angstroms. Zeolite 4A
3 will not adsorb propane. When zeolite A is ion-exchanged
4 with potassium so that its chemical composition becomes
5 $K_{12}[(AlO_2)_{12}(SiO_4)_2] \cdot xH_2O$, its effective diameter becomes
6 3 \AA and hence is known as 3A. It adsorbs H_2O , NH_3 , and
7 methanol but not ethane.
8 If zeolite A is exchanged with sufficient of a
9 multivalent cation, e.g., Ca, the effective pore diameter
10 can become 5 \AA , and such material is designated as 5A.
11 This material will adsorb n-paraffins such as n-heptane.
12 It is well known, e.g., by reference to the literature that
13 at least 25% of the Na ions have to be exchanged with cal-
14 cium to enable its pore diameter to increase in size (See,
15 e.g., U.S. 3,024,968, col. 3, lines 36-44). Profound
16 changes in adsorption behavior also occur when greater than
17 25% of the sodium ions are exchanged with a multivalent
18 cation, e.g., Ca. In accordance with the present invention
19 the various forms of zeolite are ion-exchanged with zinc
20 or cadmium, preferably zinc; and where the pore openings
21 of the zeolite are of lesser effective diameter than 5 \AA
22 the zeolite is nonetheless suitable if the diameters of
23 the pore size opening can be increased by exchange to pro-
24 vide pore openings of about 5 \AA , and greater. Of course,
25 zeolite with pore size diameters initially greater than
26 5 \AA effective pore size diameter need only be ion-exchanged
27 with zinc or cadmium, preferably zinc, to render them
28 suitable for use in accordance with the present invention.

29 With continued reference to the Table, it will
30 be observed that zinc exchange with chabazite improves its
31 capacity, and the material can also be regenerated by
32 hydrogen. Although the capacity is generally less than
33 that of Zn4A, chabazite is structurally more stable in acid
34 environments. The other acid resistant zeolites, mordenite
35 and erionite, also show improved capacity for H_2S adsorp-
36 tion upon Zn exchange.

37 A feature of this invention lies in the improved

1 selectivity of the ion-exchanged zeolites of this
2 invention for H₂S removal from reformer recycle gas.
3 This permits the realization of higher activity, yields
4 and stability for reforming catalysts, notably bimetallic
5 catalysts. Unlike ZnO, the Zn zeolites also serve to
6 remove water and to be easily regenerable with hydrogen
7 stripping.

8 It is apparent that various modifications and
9 changes can be made without departing from the spirit
10 and scope of the invention.
11 For example, the ion-exchanged molecular sieves
12 of this invention can be used in combination with metal
13 alumina spinels, by charging each type of adsorbent to
14 guard chambers and using the guard chambers in series. The
15 ion-exchanged molecular sieves show good sulfur adsorption
16 properties, and superior water adsorption properties. The
17 metal alumina spinels show superior sulfur adsorption pro-
18 perties.

0056197

CLAIMS:

1. A process for the removal of sulfur from a moisture-bearing, sulfur-containing hydrocarbon process stream characterized by contacting said stream with a particulate mass of zeolite sufficiently ion-exchanged with zinc or cadmium to provide pore size openings of about 5Å (5×10^{-10} m), and greater, to adsorb sulfur thereon, and thereafter contacting said ion-exchanged zeolite after completion of the sulfur sorption cycle with an essentially non-reactive gas or reducing gas at elevated temperature thereby desorbing the sulfur and regenerating the sorbent.
2. The process of Claim 1 characterized in that the ion-exchanged zeolite is sodium zeolite A ion-exchanged with zinc sufficient to replace at least about 25 percent of the sodium of the original zeolite A.
3. The process of Claim 1 or Claim 2 characterized in that the ion-exchanged zeolite is zinc-exchanged zeolite A or zinc exchanged chabasite.
4. The process of any one of Claims 1 to 3 characterized in that the gas employed to desorb the sulfur from the ion-exchanged zeolite is comprised of hydrogen.
5. The process of Claim 4 characterized in that the hydrogen is contacted with said zinc-exchanged zeolite sorbent at temperatures ranging from about 204.4°C (400°F) to about 648.9°C (1200°F), preferably at temperatures ranging from about 426.7°C (800°F) to about 537.8°C (1000°F).
6. A process of any one of Claims 1 to 5 characterized in that the process is carried out in a series of on-stream reactors and the non-reactive gas or reducing gas is a vaporous effluent rich in hydrogen recycled from the last reactor in the process series.

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European Patent
Office

EUROPEAN SEARCH REPORT

Application number

EP 81306172.8

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages (including references to page or line numbers)	Relevant to claim(s) ...	CLASSIFICATION OF THE APPLICATION (Int.Cl.)
A	GB - A - 1 352 904 (UNION CARBIDE CORPORATION) * Claims; page 1, line 68 - page 2, line 410; -page 3, lines 11 - lines 74-115 *	1,4,6	C 10 G (25/03) C 10 G (25/12) C 07 C (7/13)
A	GB - A - 1 326 630 (UNION CARBIDE CORPORATION) * Claims; page 1, line 62 - page 2, line 59; page 3, line 42 *	1,4-6	
A	GB - A - 1 173 388 (VEB LEUNA-WERK "WALTER ULRICH") * Page 2, lines 69-77 *	1-3	C 10 G 25/00 C 07 C 7/00 B 01 J
A	US - A - 3 620 969 (PHILIP HAIN TURNOCK et al.) * Claims; column 2, line 4 - column 3, line 45 *	1,4-6	
A	US - A - 3 211 644 (E.L. CLARK) * Claims; column 2, line 7 - column 3, line 39 *	1,4-6	
X The present search report has been drawn up for all claims			CATEGORY OF CITED DOCUMENTS X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: earlier-patent document, but published on, or after, the filing date of the application D: document cited in the application L: document cited for other reasons &: member of the same patent family, corresponding document
Place of search	Date of completion of the search	Examiner	
VIENNA	07-04-1982	STÖCKLMAYER	

U.S. PATENT AND TRADEMARK OFFICE
REGISTRATION CERTIFICATE

REGISTRATION NO. 1,000,000
SERIAL NO. 1,000,000
FILED APRIL 1, 1970
PUBLISHED APRIL 1, 1971
REGISTERED APRIL 1, 1971

FOR THE USE IN TRADE OF THE DESIGN INDICATED
IN THE DRAWINGS, AS SHOWN IN THE DESIGN
SPECIFICATION.

THE DESIGN IS FOR A CLOTHING ARTICLE, CONSISTING OF A
SWEATSHIRT HAVING A COLLAR, A SLEEVES, AND A BODY.
THE DESIGN IS FOR THE COLOR OF THE SWEATSHIRT.
THE DESIGN IS FOR THE POSITION OF THE COLLAR,
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